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PRELIMINARY DATA ON THE UHF RADIOMETRIC RESEARCH OF SOIL WETNESS, CONDUCTED IN THE USSR, IN 1974

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G. I. Chukhray and A. M. Shutko

Translation of
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Locations of Measurement /1

1. Aircraft studies of radiation characteristics of moist soils were performed during 1974 in the following regions of the USSR:

a) Central portion of the European territory -- Meshcherskiy and Kursk sectors -- May;

b) Irrigated land in Uzbek SSR -- Namaganskiy sector -- May;

c) Steppe regions, irrigated and nonirrigated areas of the Crimean area -- August.

The radiation measurements in all of these regions and surface measurements in region (c) were performed by the Institute of Radio Engineering and Electronics, Acad. Sci. USSR, surface measurements in regions (a) and (b) were performed with the cooperation of the Institute of Geography, Acad. Sci. USSR, and the Institute of Water Problems, Acad. Sci. USSR.

2. Brief characteristics of the operating regions and agrimeteorological conditions during the time of performance of the measurements:

a) The Meshcherskiy sector is characterized by the presence of primarily meadows, swampy areas, woods and some crops on a plains terrain.

The Kursk area includes experimental sections of fields with various agricultural crops.

Due to the late thaw in the spring of 1974, this region was quite moist during the time of measurement, with areas of open water, so that no significant differences in values of moisture content in /2 the soil were observed during the experimental period.

b) One peculiarity of the Managanskiy sector is the flooded agriculture; irrigation is achieved using a ditch-drainage system. This is a plains area. The agricultural crops include primarily cotton, rice, millet and alfalfa.

The area also includes uncultivated land such as sandy desert and semidesert with sparse vegetation.

The experiments were performed in hot sunny weather without precipitation before the beginning of the spring-summer flood, so that it was dry throughout the entire period of measurements. Thus, the soil moisture content was 5-15% in the cultivated areas and not over a few percent in the desert regions.

c) The region of the Crimean area selected for the studies is north of the city of Feodosiya, includes the territory between the northern Crimean Canal and the banks of Lake Sivash and the Azov Sea, as well as a portion of the Arabatskaya Spit (Figure 1).

The landscape includes both cultivated land in the area of the canal (Figure 2-Figure 6) and uncultivated regions on the Arabatskaya Spit and the shores of Lake Sivash.

The photographs presented in Figures 2-8 give an idea of the nature of the surface and plant cover in the field areas studied. The regions selected include corn (Figure 2), sunflowers (Figure 3), beets (Figure 4), winter crops (Figure 5). Significant areas of the fields are plowed (Figure 6). The uncultivated land consists of areas of steppe and semidesert (Figure 7) and solonchak (Figure 8).

It should be noted that the most favorable conditions for studies of the dependence of radiation characteristics on moisture content were found in the regions of the Crimean area. Here there were heavy rainfalls twice during the period of the studies, and mobile sprinkler-type irrigation installations were in operation constantly. In general, the test period featured hot sunny weather. The soil moisture content varied from a few percent to several tens of percent. /3

3. Apparatus, methods of conduct of measurements, volume of studies performed.

The radiometric measurements in regions (a) and (b) were performed in the 0.8 cm and 3.4 cm wave length bands by means of radiometers installed onboard an IL-14 aircraft. The sensitivity of the radiometers was ∿0.5 K with a time constant of 1 sec.

The angular resolution of the antenna devices was 1° and 3° respectively. The electrical axis of the antenna for the 3 cm band was oriented at an angle of 60° to the horizon; in the 8 mm channel, the possibility was provided of adjusting the antenna axis between two fixed values of angle, 60 and 20°. Measurements could be performed with either vertical or horizontal polarizations.

In region (c), the measurements were also performed from an IL-18 aircraft equipped with three sets of radiometers at 3 cm, 10 cm and 20 cm wave lengths. The sensitivity of the radiometers was 0.3-1 K with a time constant of 1 sec. The angular resolution was ∿5° at 3 and 10 cm and 10° at 20 cm. The electrical axes of the antennas were oriented at 60° to the horizontal. Measurements could be performed in either vertical or horizontal polarizations.

The measurements were performed in horizontal flight at altitudes of 50-100 m to several hundreds of meters, so that the spatial resolution amounted from a few meters to a few dozens of meters. /4
The apparatus was calibrated by internal temperature standards, and was also checked during each flight by means of reference areas on the terrain such as water surfaces, dry forested or steppe areas with known physical characteristics and values of temperature.

Flights were conducted each day or at intervals of 1 or 2 days. The duration of the experiments was: in region (a) -- 5 days (10 flying hours); (b) -- 10 days (20 flying hours); (c) -- 20 days (40 flying hours).

The length of homogeneous terrain sectors varied from a few hundreds of meters to a few kilometers.

The surface measurements included determination of the temperature and moisture content of the soil at three levels, down to 15-20 cm depth, and in some areas down to depths of 50 cm and more. The distance between neighboring points for which surface measurements were performed varied from a few tens to some hundreds of meters, depending on the peculiarities of the surface. The moisture content of the soil was determined by a gravimetric (thermostat-gravimetric) method. Areas of the surface were photographed in various fields. The weather parameters of the atmosphere were also checked. Soil specimens were taken from various field sectors, and the dielectric properties of the samples were determined under laboratory conditions.

4. Some results of measurement.

Figure 9-B shows some of the results of measurements performed in 1973 in the 0.8 and 3.4 cm band from the IL-14 aircraft.

Figure 9 shows an example of synchronous recording of radiothermal signals on these wave lengths produced in a flight over cultivated fields. The sectors are: 1, plowed; 2, cornfields; 3, area with low-growing vegetation (sprouts of winter crops, cut fields). The measurements were performed immediately after a heavy rain. The data produced give us an idea of the degree of the influence of plant cover on the radiation characteristics of the surface. Figures 11-13 show the results of comparison of measured values of radiative capacity and the data of direct measurements of moisture content for various sectors of fields as 0.8 cm and 3.4 cm. The absolute accuracy of the measurements of radiative capacity is about ±0.03, agreeing with an accuracy of measurement of brightness temperature of about ±10 K. /5

The data presented show that in the cases of observation of SHF radiation from open soils, there is a clearly expressed dependence in changes in brightness temperature as a function of soil moisture content. This dependence agrees satisfactorily with model estimates and is characterized by a steepness of ∿2-3 K/% moisture.

The accuracy of estimation of the moisture content by the radiometric method in the upper layer, according to the data of 1973, is no worse than ±5% with moisture contents of 10-40%.

In the case of observation of soils, with vegetation, the shielding influence of the plant cover appears, leading to a reduction in the steepness of the brightness-moisture dependence.

Figures 14-16 show some results of measurements performed in 1974 in the Crimean area. Figure 14 shows an example of synchronous recording of radiothermal signals at 3.4 cm, 10 cm and 20 cm, produced in the sector between Lake Sivash and the northern Crimean Canal immediately after a heavy rainfall. The precipitation fell /6 primarily over a large plowed field. Synchronous correlated changes in radiobrightness at all wave lengths are observed. Uneven moistening is noted.

The data presented in Figure 15 illustrate the degree of changes in radiobrightness of the same areas of the surface during drying of the soil.

An example of the recording of the radiothermal signal at 3.4 cm produced in a flight over an irrigated field with sprouts of winter crops is presented in Figure 16.

The preliminary results of processing of the data show that the steepness of the brightness-moisture dependence in the 3-20 cm wave band is about 2.2 ± 0.5 K/% moisture for open-soil sectors.

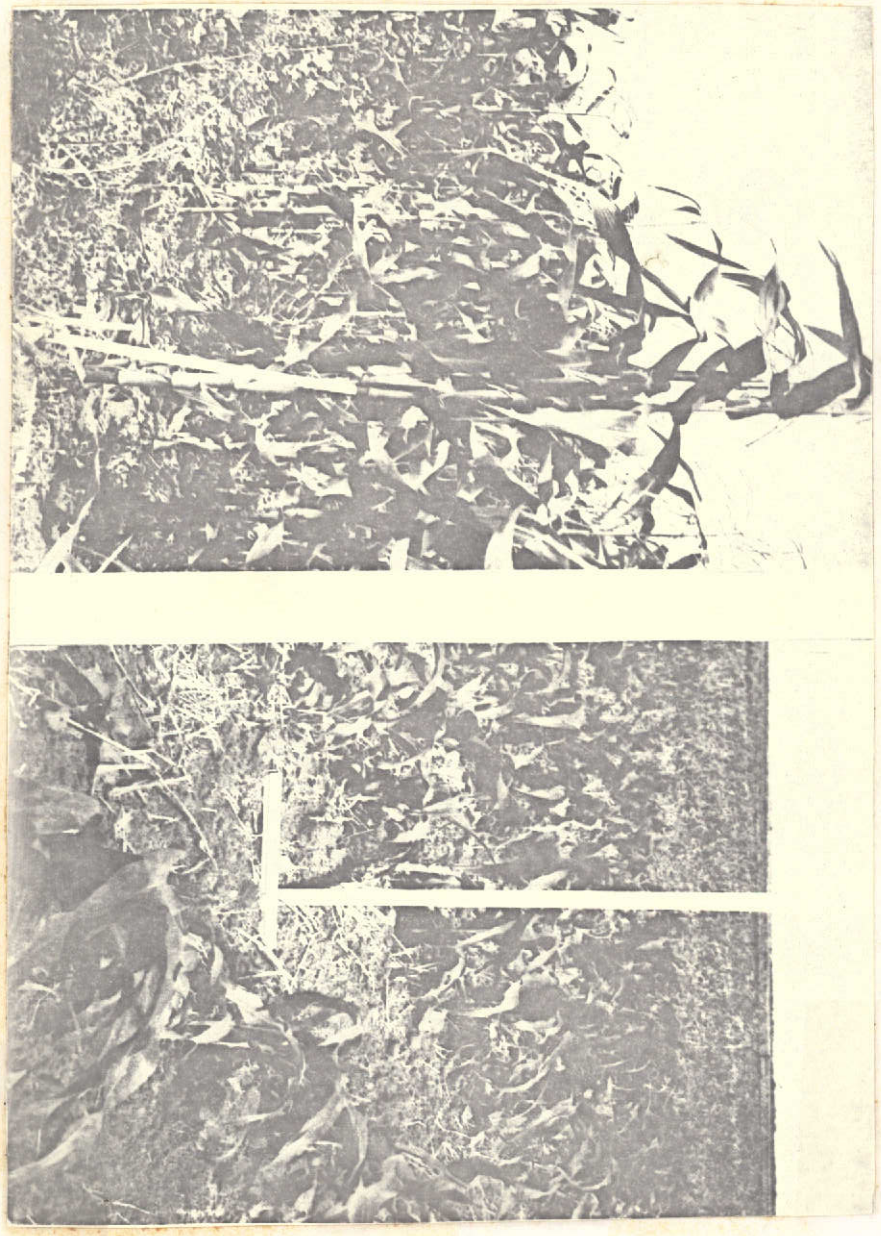

Figure 2. Photographs of Cornfield Sectors.

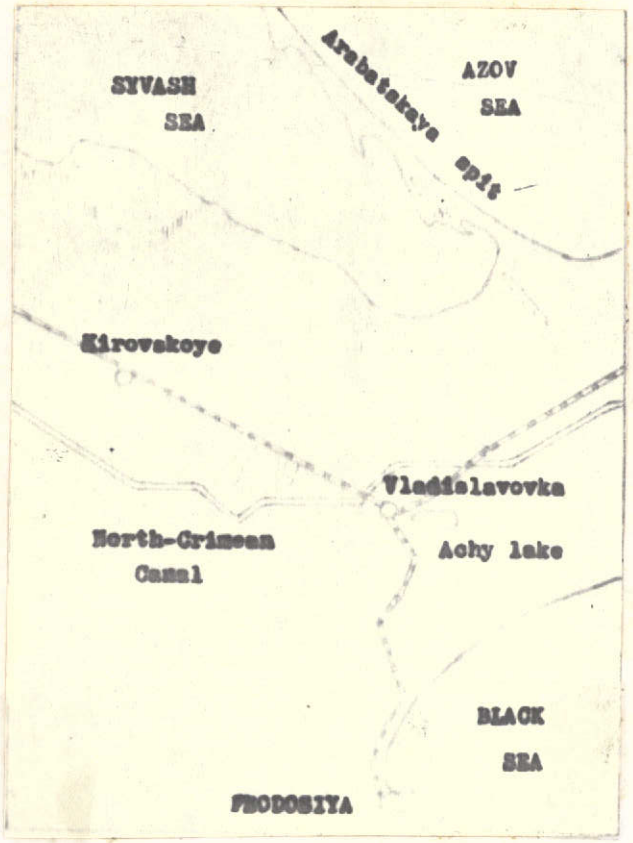

Figure 1. Diagram of Region of Operations in Crimean Area

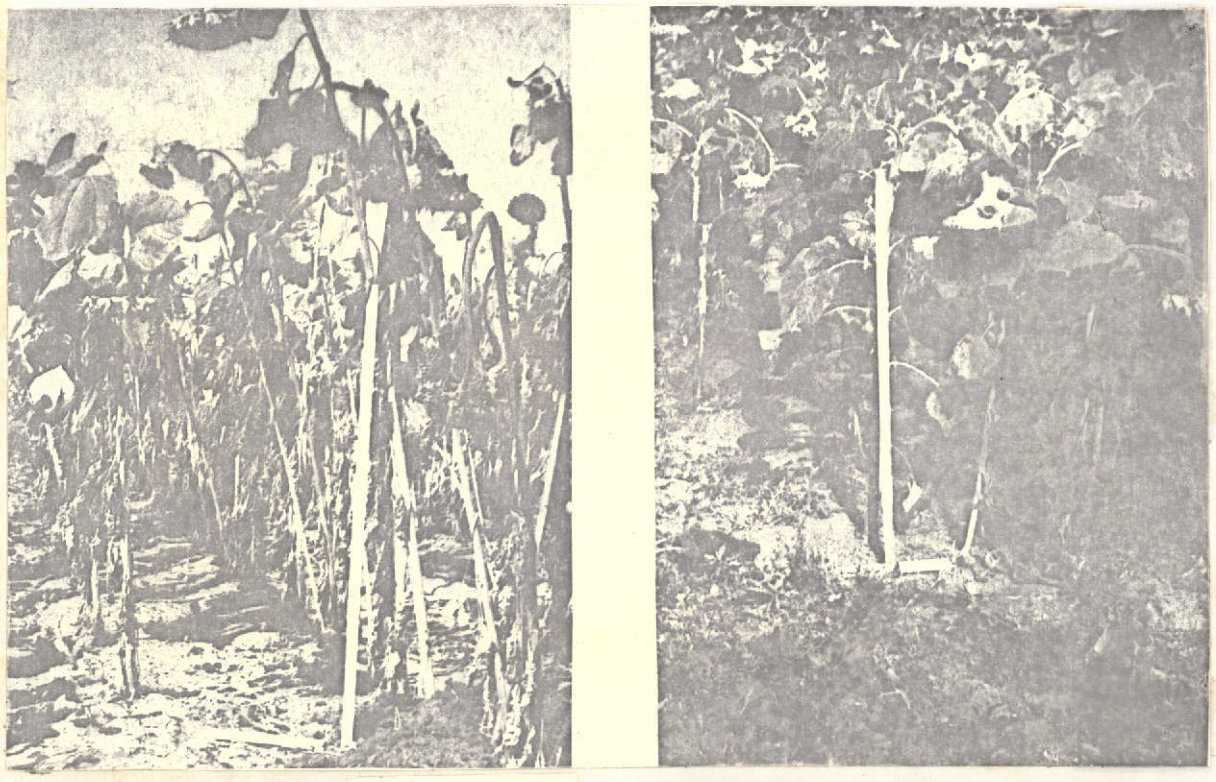

Figure 3. Photographs of Sunflower Field Sectors

Figure 4. Photograph of
Beet Field Sector

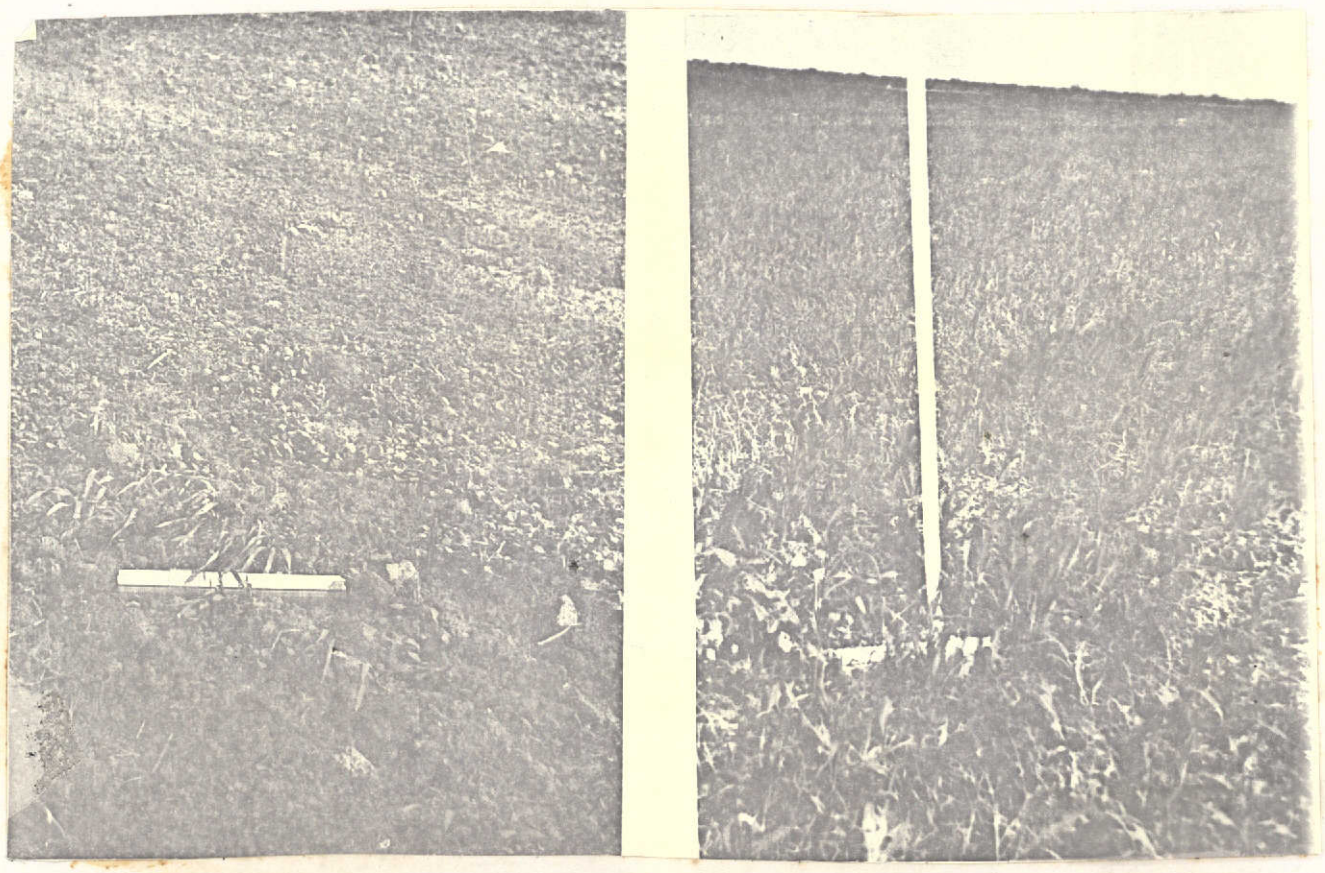

Figure 5. Photographs of Wheatfield Sectors

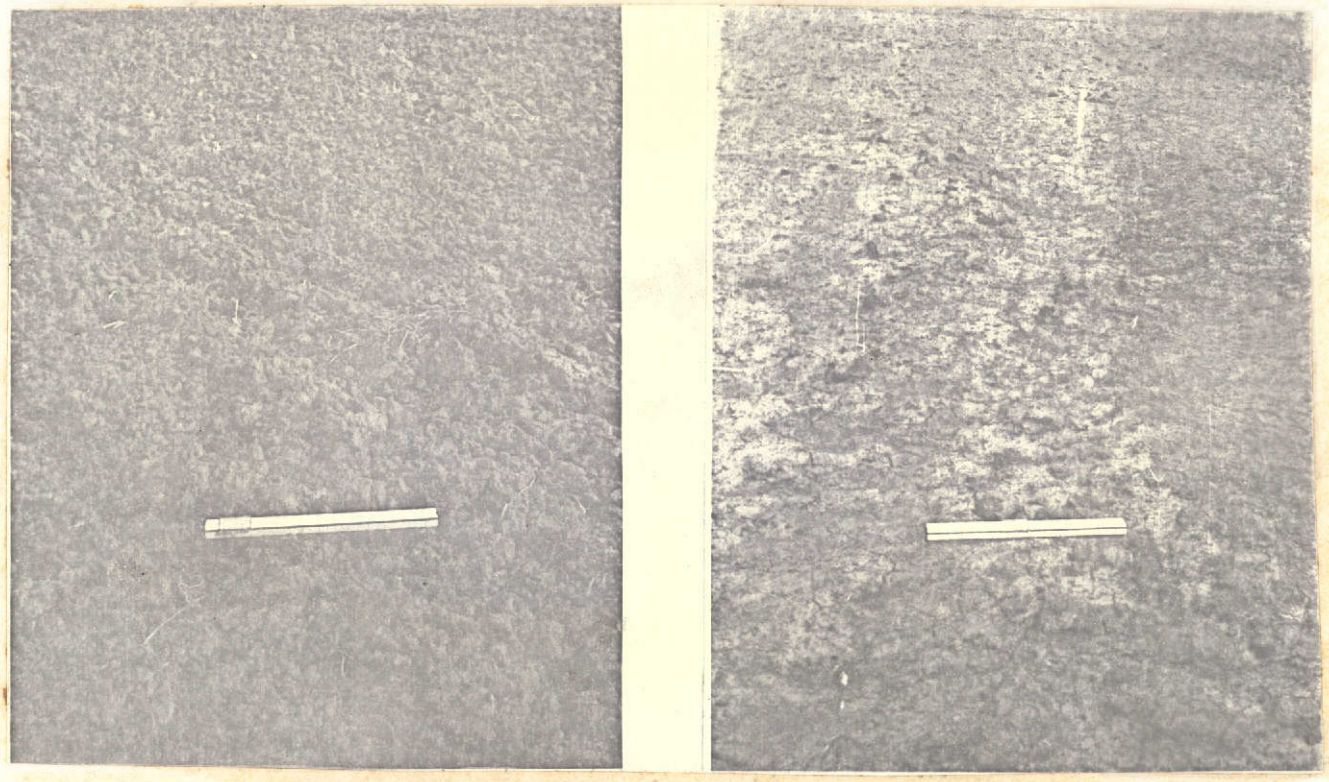

Figure 6. Photographs of Plowed Fields.
a) Dried field; b) Field after rain.

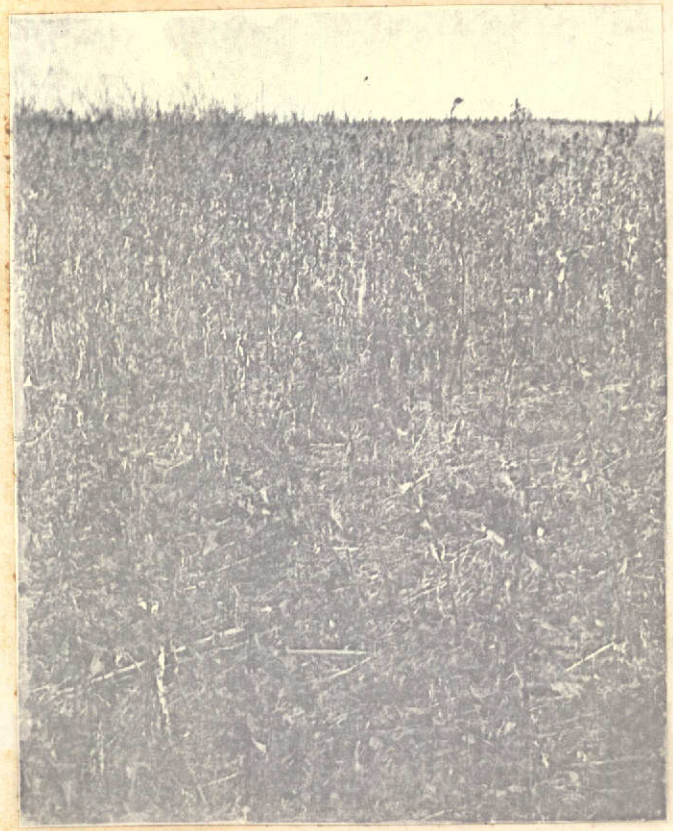

Figure 7. Photograph of Steppe Sector

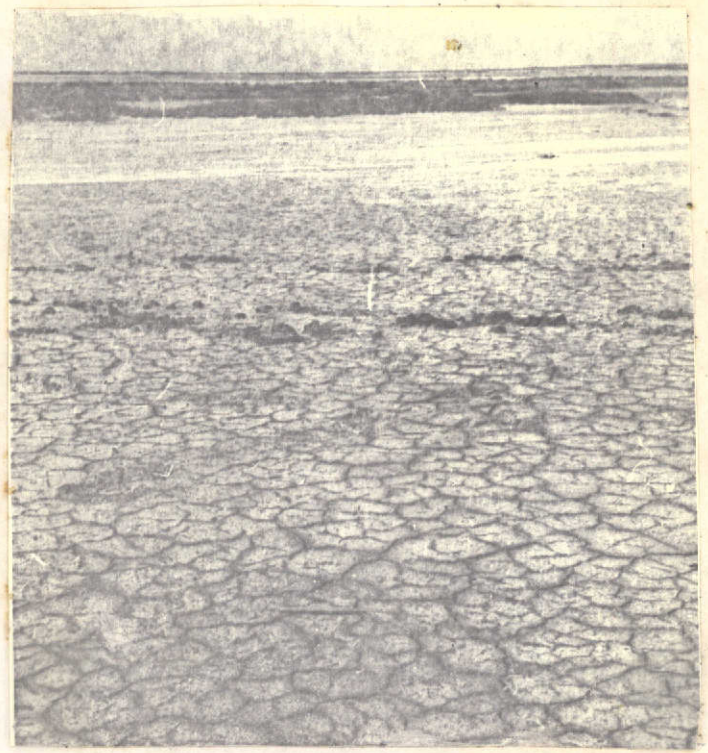

Figure 8. Photograph of Solonchak Sector

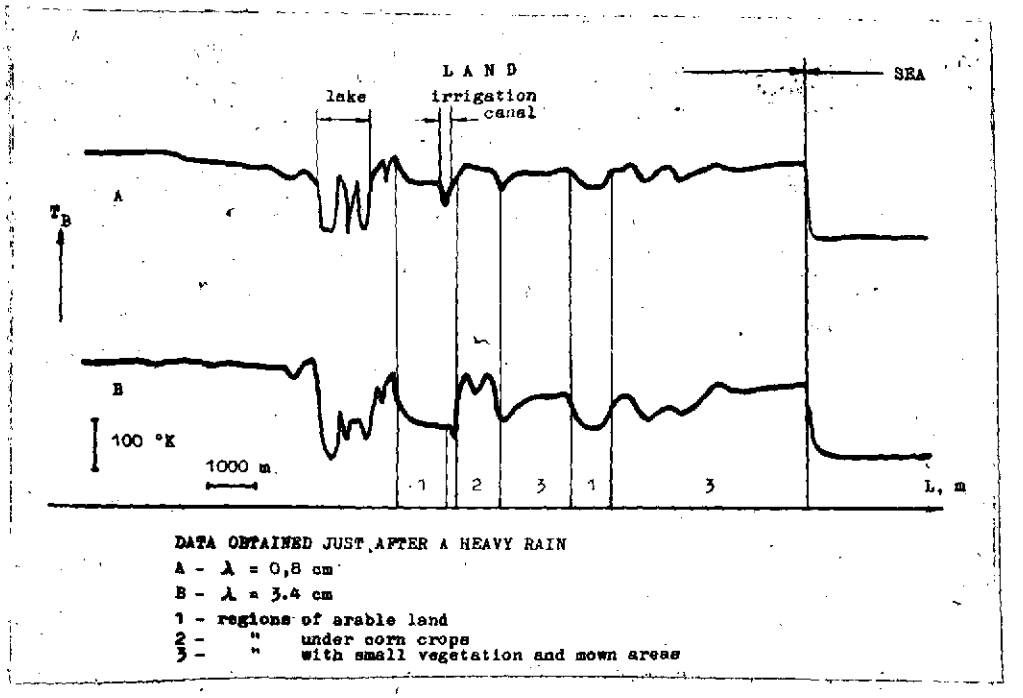

Figure 9.
An example of achieving data from the synchronous measurements of the radio brightness over wet regions in the wavelengths:
A - 0.8 cm (ϑ_G = 20°, "g.p.")
B - 3.4 cm (Θ_G = 60°, "g. p.")

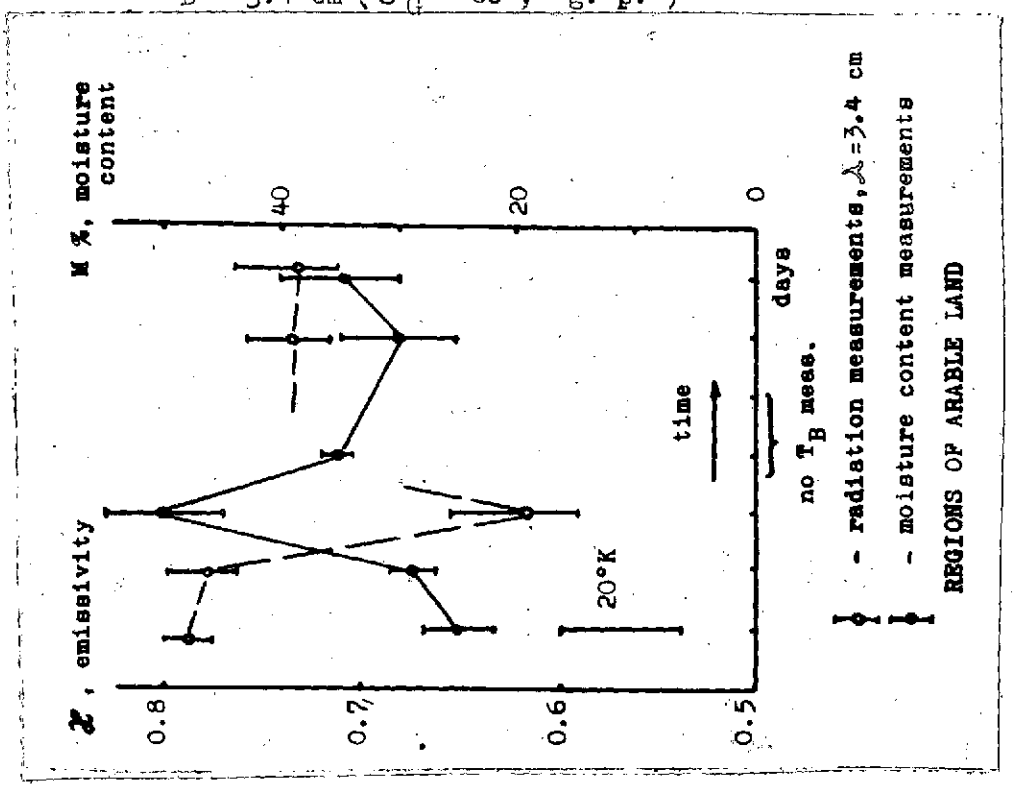

Figure 10. Time Variations of Moisture Content and Radiative Capacity of Soil (Synchronous measurements)

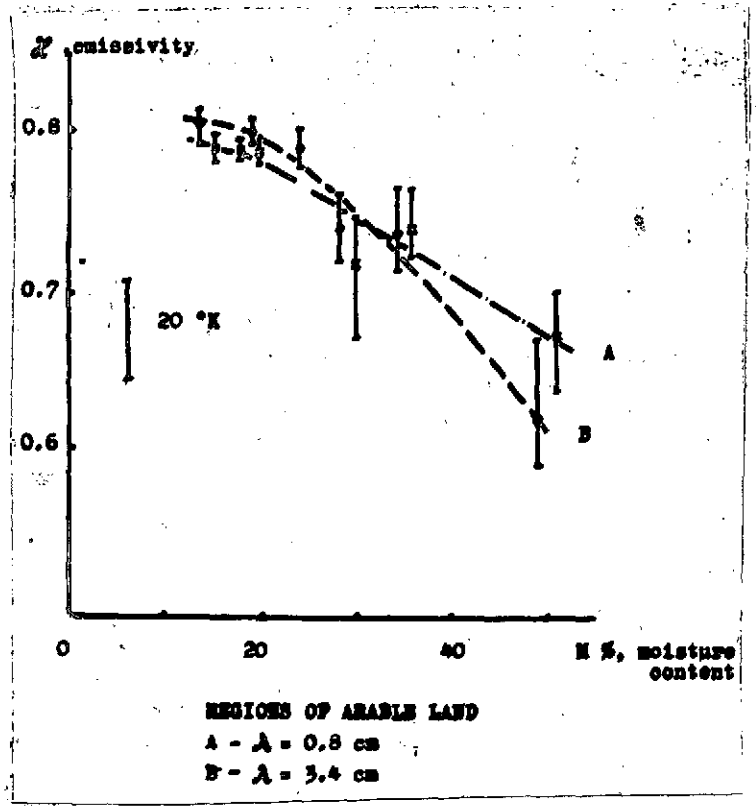

Figure 11. Comparison of Data of Synchronous Measurements of Radiobrightness and Moisture Content of Soil in Plowed Field Sectors

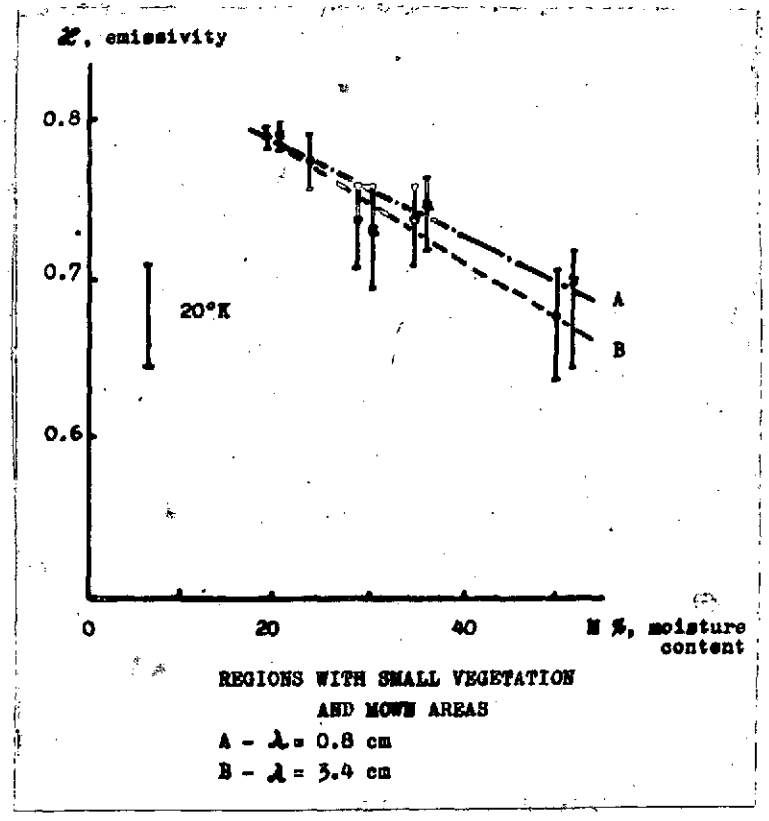

Figure 12. Comparison of Data of Synchronous Measurements of Radiobrightness and Moisture Content of Soil in Regions with Small Vegetation ($h \leq 0.5$ m)

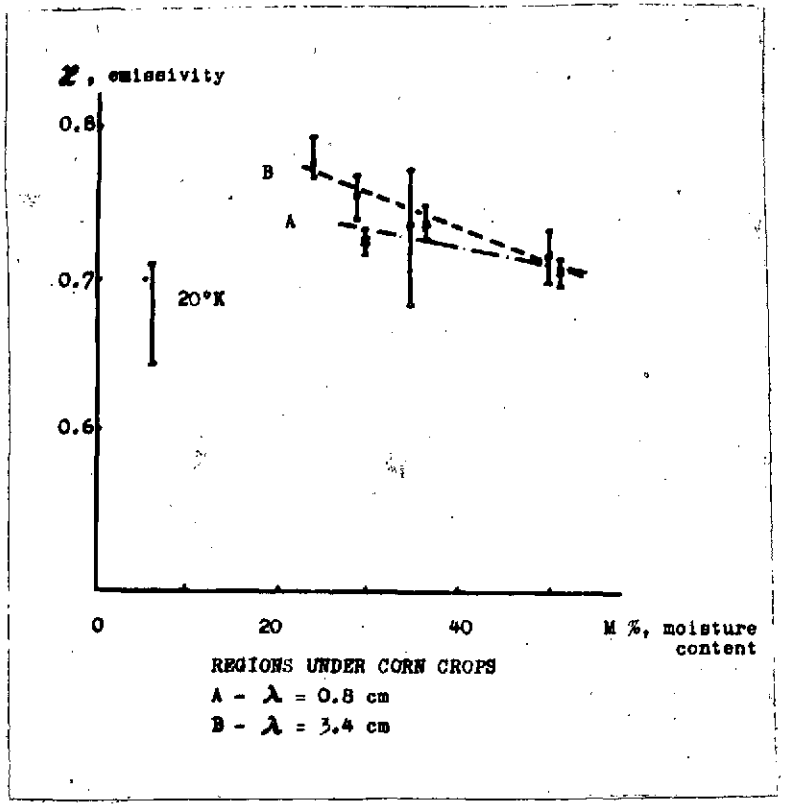

Figure 13. Comparison of Data of Synchronous Measurements of Radiobrightness and Moisture Content of Soil in Cornfield Areas ($h \geq 1$ m)

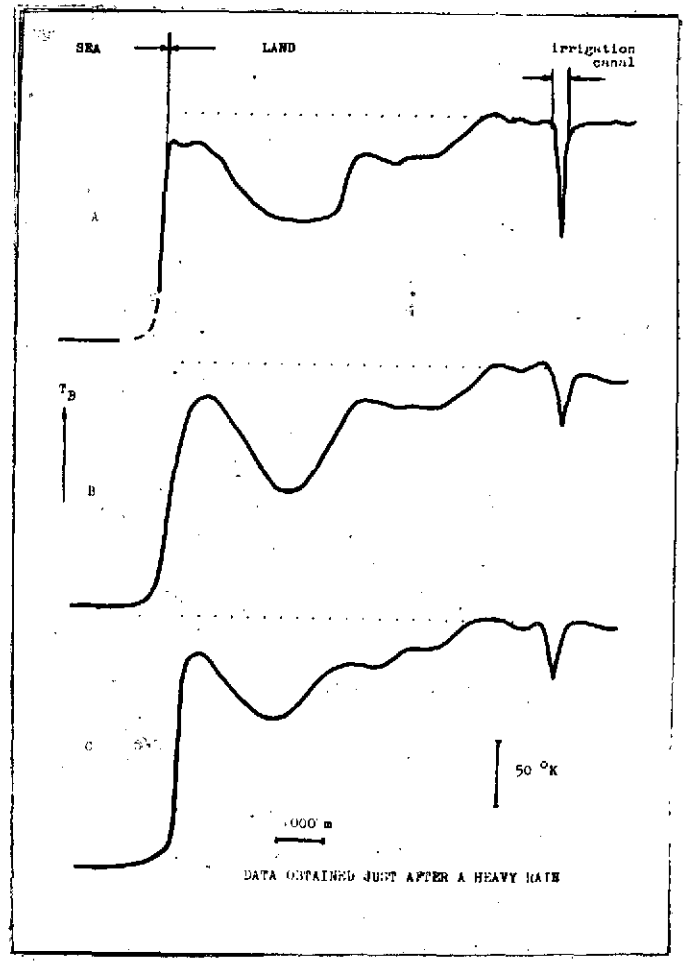

Figure 14. Example of Realization of Data of Synchronous Measurement of Radiobrightness over Moist Regions in Wave Length Bands

A - 3.4 cm (θ_G = 60°, h.p.)

B - 10 cm (")

C - 20 cm (" v.p.)

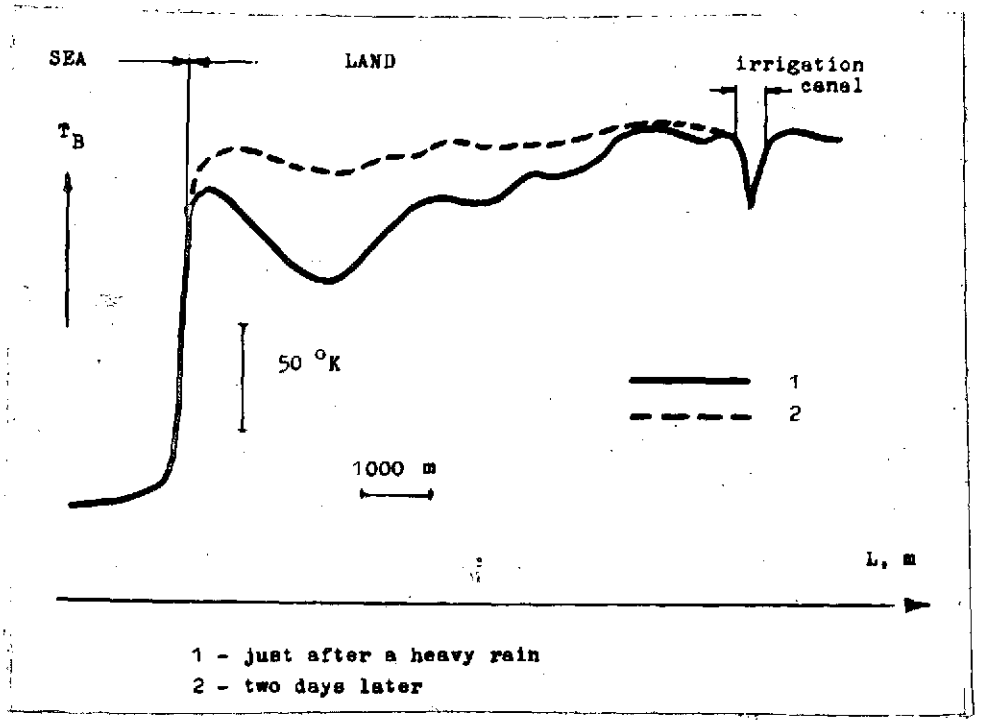

Figure 15. Example of Realization of Data of Measurement of Radiobrightness Over Moist Regions at Two-Day Interval for 20 cm Wave Length (θ_G = 30°, v. p.)

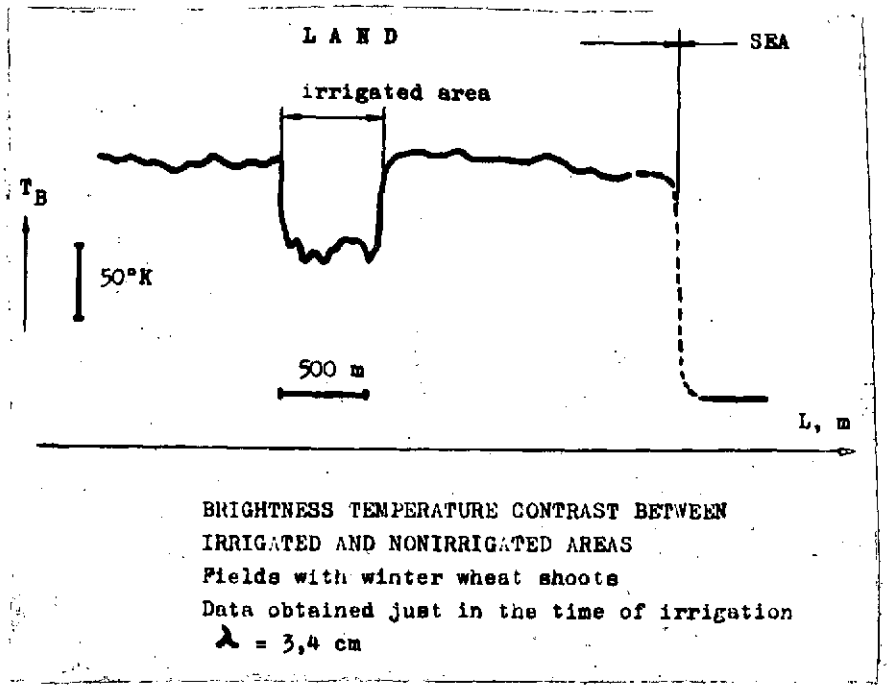

Figure 16.
(θ_G = 60°, h.p.)